

Figure 3.3.3. Proportion of the South Carolina's estuarine habitat that ranks as good (green), fair (yellow) or poor (red) using the integrated sediment quality score when tidal creek and open water habitats are combined and compared on an annual basis, and for tidal creek and open water habitats considered separately.

### 3.4 Biological Condition

#### Phytoplankton

Phytoplankton biomass and composition serve as valuable indicators of estuarine health because these primary producers respond rapidly to increases in nutrient loading. Even short-term increases in nutrient inputs can promote blooms of algal species that are often present but not overabundant in balanced, healthy estuarine systems. Increased nutrient inputs promote a complex set of environmental responses, beginning with shifts in algal composition and leading to blooms of harmful species that have deleterious impacts on biota (Bricker *et al.*, 1999). Harmful species are defined by the potential to produce blooms or toxins that have negative effects on biological systems (causing fish kills for example) and in some cases cause human health problems (such as paralytic shellfish poisoning).

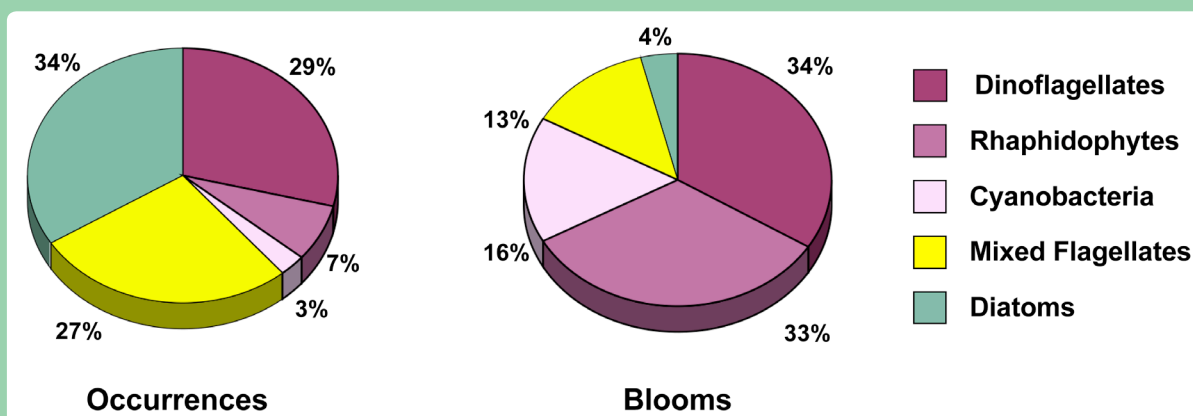
Most harmful algal species fall within the cyanobacteria, dinoflagellate and raphidophyte groups, although not all species within these taxa are harmful and some may appear within the diverse assemblages of pristine estuarine systems. These



Fishkill in a stormwater detention pond caused by a toxic cyanobacterial bloom. Photo credit: SCAEL

### Box 3.4.1 Harmful Algae and Coastal Stormwater Ponds

In coastal stormwater ponds, the algal assemblage is dominated by harmful species that frequently produce blooms ( $> 1000$  cell/ml). The algae producing these blooms are most frequently classified as dinoflagellates, raphidophytes, and cyanobacteria, which all have potentially toxic species. In the rapidly urbanizing South Carolina coastal zone, intensive landscape maintenance and turf management are significant sources of non-point source pollutant and nutrient loadings (Lewitus, *et al.*, 2003). The stormwater best management practice of choice in this region is wet detention ponds. Typically, stormwater is piped directly into the ponds, but their capacity for processing pollutants is limited. These highly eutrophic ponds are “hot spots” for harmful algal blooms, many associated with measured toxins, fish kills, or shellfish health effects. Pond nutrient accumulations may also impact estuarine eutrophication through surface or groundwater transport (Pinckney *et al.*, 2001). The pie charts below show the percent occurrence (by group) of all species and percent blooms (by group) of all blooms ( $>1000$  cells/ml) between 2000 and 2005. During this period 325 blooms were recorded in brackish detention ponds and 25 in South Carolina's estuarine and coastal environment. Note that most of the blooms are attributed to dinoflagellates, raphidophytes and cyanobacteria.



*The percent occurrence and percent of blooms of harmful species in eutrophic coastal locations (detention ponds and nearby impaired estuaries) from the larger South Carolina Harmful Algal Bloom database between 2000 and 2005.*

taxa do, however, respond rapidly to increased nutrient levels and will dominate the biomass in enriched brackish environments (Ramus *et al.*, 2003). Unfortunately, there are far too many examples of these enriched brackish environments in South Carolina coastal zone. Stormwater ponds along the coast serve as incubators for harmful algal blooms and appear to be acting as a source of these harmful species into the adjacent estuaries (Box 3.4.1).

In contrast to this scenario of eutrophic water which reflects the anthropogenic effects of development, the majority of sites investigated in the 2003-2004 SCECAP program appeared to be in good condition and supported a diverse and desirable phytoplankton assemblage. The CHEMTAX

evaluation of the percent biomass contribution by taxa demonstrated that 86-88% of the biomass was “healthy” (diatoms or mixed flagellates) and 13-14% was potentially harmful (dinoflagellates, raphidophytes or cyanobacteria). Diatoms are common in pristine estuaries and contribute efficiently to the food web (Lewitus *et al.*, 1998). They contributed 48% of the biomass in the open water habitats and 41% of the biomass in the tidal creek habitats. Mixed flagellates were also dominant, and, while not as effective in transferring carbon and energy through the aquatic food web as the diatoms, they are considered desirable phytoplankton. The average relative biomass contributed by mixed flagellates was 39% in open water and 45% in tidal creek habitats (Figure 3.4.1). The smallest fraction of the biomass

was contributed by the potentially harmful taxa including some dinoflagellates, raphidophytes and cyanobacteria. Only 13% of open water and 14% of the tidal creek site biomass was attributed to harmful taxa (Figure 3.4.1).

While the average percentage of harmful species at SCECAP sites is low for both tidal creek and open sites, there were some stations where the biomass of potentially harmful species exceeded 20% (Figure 3.4.2). Dinoflagellate percent biomass was elevated at six stations, while percent cyanobacterial biomass exceeded 20% at 12 stations. The station with the highest percent harmful cyanobacteria had a toxicity bioassay score indicative of a high probability of toxic sediments, and the station with the highest percent dinoflagellate relative biomass had an

### Phytoplankton Composition by Stratum

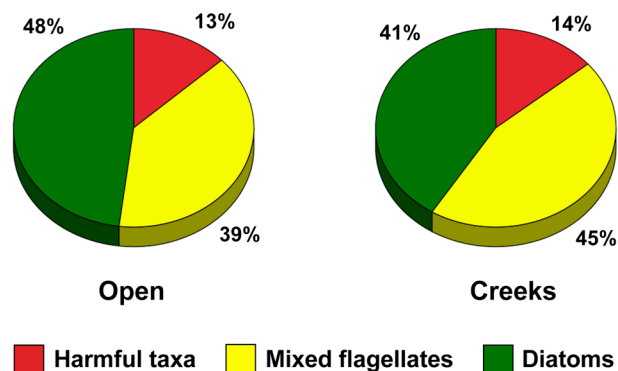


Figure 3.4.1. The percent contribution of diatoms, harmful taxa, and mixed flagellates to total phytoplankton community pigment biomass based on the mean of 2003-2004 samples from SCECAP open water and creek sites.

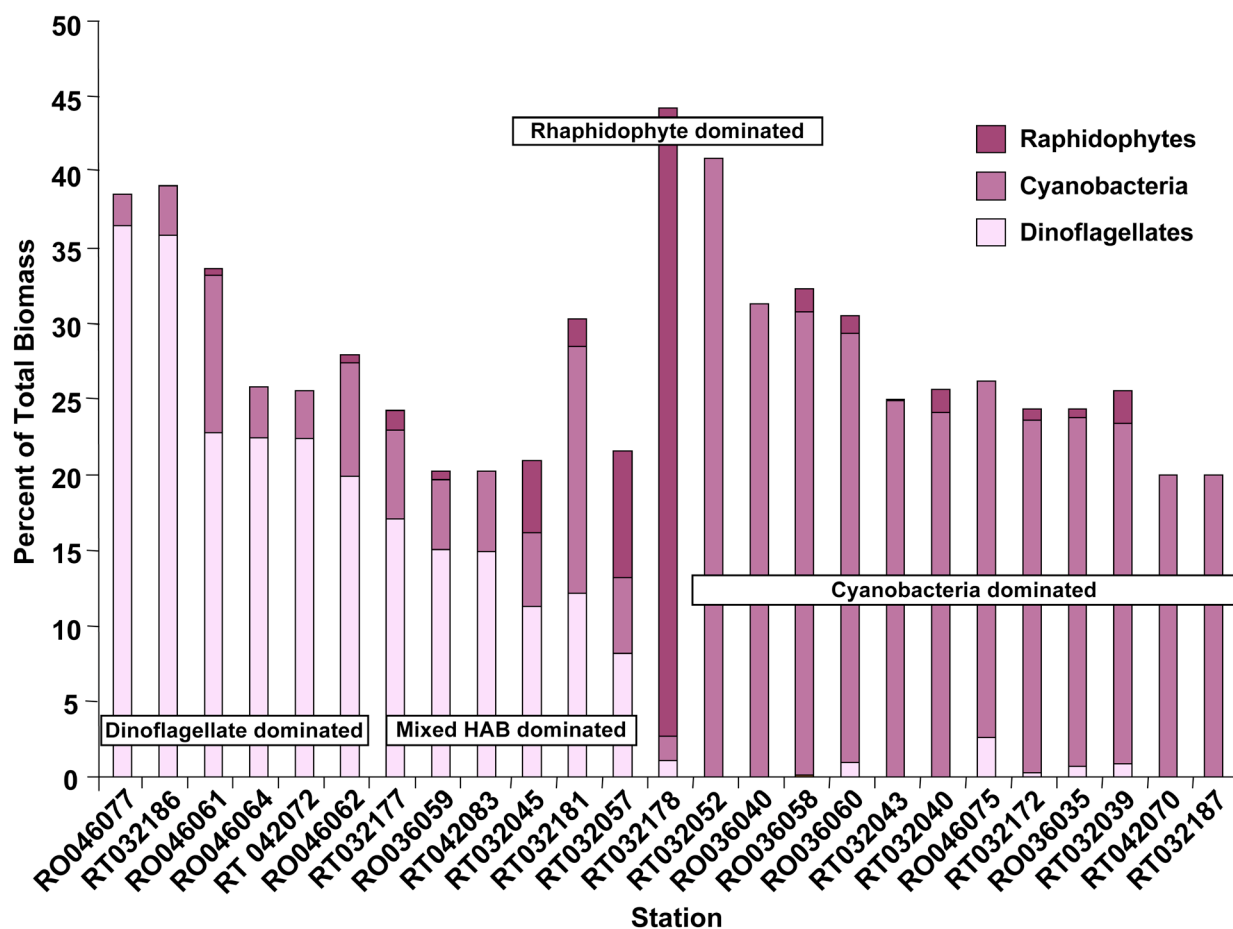


Figure 3.4.2. Percent biomass of harmful groups from stations with >20% of biomass attributed to potentially harmful taxon.

ERM-Q score indicative of high contaminant risk. Six stations had a mixed assemblage of harmful algal taxa and one station had primarily raphidophytes with *Heterosigma akashiwo* comprising 45% of the algal biomass (Figure 3.4.2). This station was within the Bulls Bay region where the South Carolina Algal Ecology Laboratory (SCAEL) documented a large (50 mi<sup>2</sup>) offshore bloom of *Heterosigma akashiwo* in April 2003 (Keppler *et al.*, 2005).

The effects of the prolonged drought from 1999-2002 and a return to higher rainfall during 2003 were apparent in a decrease in salinity and relatively high nutrients levels during 2003 (see Section 3.2). Species that are generally confined to salinities of < 5 ppt include the cyanobacteria, euglenoids, and chlorophytes. These three groups were not present in the samples collected during 2001-2002, but did appear in the 2003 assemblages at seven tidal creek sites and nine open water sites (Figure 3.4.3). The salinity of the sites containing the euglena species varied from 0.1- 17.9 ppt, while the average salinity at sites with cyanobacterial species present was 13.9 ppt for creeks and 14.1 ppt for open water sites.

Another group which increased in diversity during 2003-2004 was the raphidophytes. These

potentially ichthyotoxic (fish-killing) species tend to occur in brackish water ranging from 10-25 ppt, and can bloom rapidly in response to nutrient-rich freshwater inflows (Honjo, 1993). The salinity ranges of the raphidophyte species noted in the 2003-2004 SCECAP samples was from 12 - 29 ppt (Figure 3.4.3).

While the overall biomass of the phytoplankton is attributed to desirable species, there were harmful species present during the 2003-2004 sampling period. Table 3.4.1 lists the number of occurrences in the SCECAP phytoplankton database of the potentially harmful species. The cyanobacterial species noted are all potential bloom formers and most can produce toxins (hepatotoxins and neurotoxins). Only one diatom species of concern was documented, but this species (*Pseudo-nitzschia cf. delicatissima*) can produce domoic acid, a potent neurotoxin (Horner *et al.*, 1997). Many of the dinoflagellates listed are capable of producing blooms and have been associated with fish kills in South Carolina and around the world. A few of the known toxin producers documented by SCECAP included *Alexandrium*, *Gambierdiscus* and *Prorocentrum*. The final group noted are the raphidophytes that frequently have been associated with fishkills in South Carolina stormwater

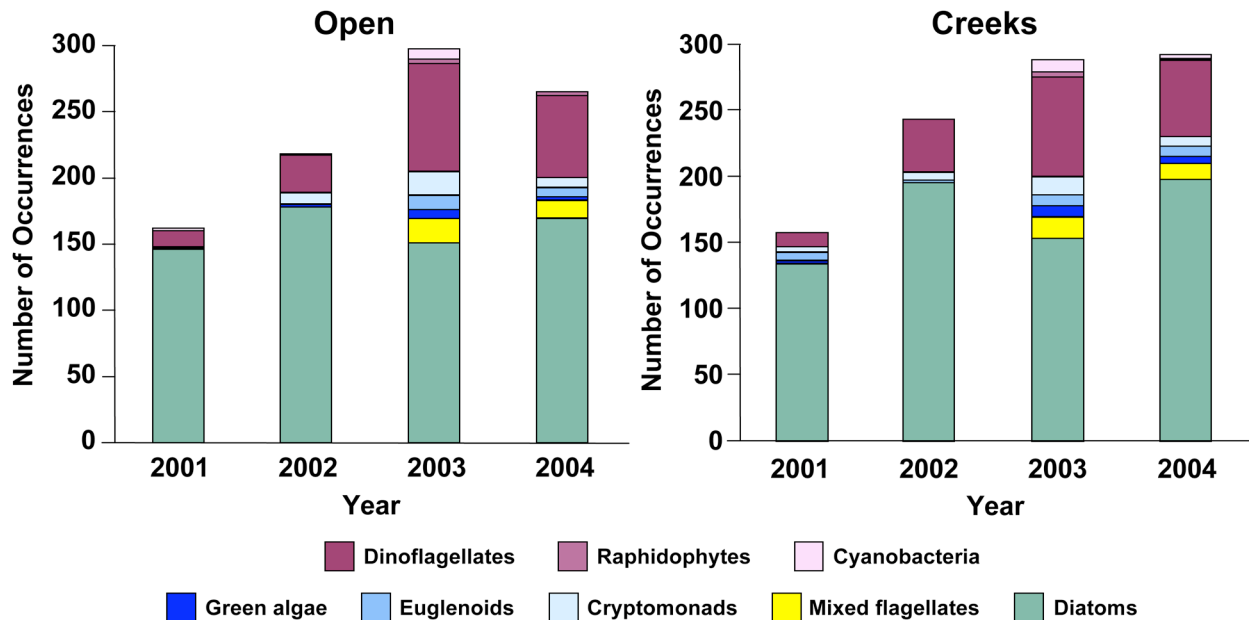


Figure 3.4.3. Occurrence of dominant taxonomic groups in open water and tidal creek sites. The number of taxa increased during the current study period coincident with a decrease in salinity, and the additional groups (green algae, euglenoids, and cyanobacteria) tend to occur in lower salinity water.

Table 3.4.1 Number of open water and tidal creek stations where potentially harmful phytoplankton species were identified. Included are whether each species is toxin-forming (toxic) or bloomforming (blooms) as well as the toxins and/or ecological effects produced.

Phytoplankton Species	Open Water	Tidal Creek	HAB Category	Known Toxins, Effects
<b>Cyanobacteria</b>				
<i>Anabaena</i> sp.		1	toxic	Anatoxins, Saxitoxins, Microcystins, LPS
<i>Aphanizomenon</i> sp.		1	toxic	Saxitoxins, Cylindrospermopsins, LPS
<i>Microcystis aeruginosa</i>		1	toxic	Microcystins, LPS
<i>Microcystis incerta</i>		1	blooms	
<i>Oscillatoria</i> sp.	6	6	toxic	Anatoxin, LPS
<i>Planktothrix</i> sp.		1	toxic	Anatoxin, LPS
<i>Pseudanabaena</i> sp.	1	1	toxic	unknown neurotoxin
<i>Spirulina</i> sp.	1		blooms	
<b>Diatoms</b>				
<i>Pseudo-nitzschia cf. delicatissima</i>	1	1	toxic	Domoic acid
<i>Pseudo-nitzschia</i> sp.	9	8	some toxic	Domoic acid
<b>Dinoflagellates</b>				
<i>Akashiwo sanguinea</i>	14	20	blooms	
<i>Alexandrium</i> sp.	1		toxic	Hemolysin, PSP-causing compounds
<i>Amphidinium</i> sp.	5	2	toxic	Hemolysins
<i>Gambierdiscus</i> sp.	1		some toxic	Ciguatoxin- and Maitotoxin-like compounds
<i>Gyrodinium pingue</i>	4	7	blooms	associated with fishkills in SC
<i>Gyrodinium instriatum</i>	1	1	blooms	associated with fishkills in SC
<i>Heterocapsa rotundata</i>	28	20	blooms	associated with fishkills in SC
<i>Heterocapsa triquetra</i>	1		blooms	associated with fishkills in SC
<i>Karlodinium micrum</i>	16	8	toxic	karlotoxin, ichthyotoxic
<i>Krypto-imposter</i>	4	12	blooms	associated with shellfish stress in SC
<i>Kryptoperidinium foliaceum</i>	4	21	blooms	associated with shellfish stress in SC
<i>Pfiesteria-like organism</i>	2	5	toxic	associated with fishkills in SC
<i>Prorocentrum c.f. lima</i>		1	toxic	Okadaic acid, Dinophysis toxins 1 & 2
<i>Prorocentrum micans</i>	1		blooms	associated with fishkills in SC
<i>Prorocentrum minimum</i>	4	3	toxic	Unknown toxins
<i>Prorocentrum</i> sp.		1	some toxic	Okadaic acid, Dinophysis toxins 1 & 2
<b>Raphidophytes</b>				
<i>Chattonella subsalsa</i>	2		blooms	associated with fishkills in SC
<i>Chattonella verruculosa</i>		1	toxic	ichthyotoxic
<i>Fibrocapsa japonica</i>	1		toxic	ichthyotoxic
<i>Heterosigma akashiwo</i>	2	2	toxic	ichthyotoxic
<i>Heterosigma</i> sp.	1	2	toxic	ichthyotoxic

ponds. The raphidophytes *Heterosigma akashiwo*, *Fibrocapsa japonica*, and *Chattonella subsalsa*, also found by SCECAP in South Carolina's coastal waters, have been implicated in numerous fish kills globally (Honjo, 1993).

While none of these species were present in high abundance and no toxins were detected in the samples collected for the SCECAP study, they are present and potentially capable of responding rapidly to future anthropogenic nutrient enrichment. It is imperative that the development of our coastline be tempered by thorough urban planning and effective watershed management in order to prevent harmful algal blooms and ensure the health of our estuaries.

### Benthic Communities

Benthic macrofauna serve as ecologically important components of the food web by consuming smaller organisms living in or on the sediments, detritus, or planktonic food sources and in turn serving as prey for finfish, shrimp, and crabs. Benthic macrofauna are also relatively sedentary, and many species are sensitive to varying environmental conditions. As a result, benthic organisms are important biological indicators of water and sediment quality and are useful in monitoring programs to assess overall coastal and estuarine health (Hyland *et al.*, 1999; Van Dolah *et al.*, 1999).

Mean density of benthic organisms across all stations sampled during the 2003-2004 study period varied from 63 to 37,113 individuals/m<sup>2</sup> (mean = 3,628 individuals/m<sup>2</sup>). The mean density of organisms collected in open water habitats (4,182 individuals/m<sup>2</sup>) was greater than the density in tidal creek habitats (3,076 individuals/m<sup>2</sup>), although the difference was not statistically significant ( $p = 0.952$ , Figure 3.4.4). The density of benthic organisms in open water habitats has been consistently higher than in tidal creek habitats in all three surveys conducted by SCECAP to date (Van Dolah *et al.*, 2002a; 2004a). The mean density of organisms collected during the 2003-2004 study period was 25% lower than the mean density collected in the 1999-2000 study period (average = 4,722 individuals/m<sup>2</sup>) and 30% lower than those collected in 2001-2002 (average = 5,208 individuals/m<sup>2</sup>). The first two study periods (1999-2002) occurred during a drought period in South

Carolina (South Carolina State Climatology Office), while the current study period began after the drought was lifted in April, 2003. The differences in benthic faunal density may reflect changes in salinity between the previous study periods when drought conditions persisted (Van Dolah *et al.*, 2002a; 2004a) and the current study period when more normal rainfall patterns returned (see section 3.2 and Box 3.4.2).

The overall number of species (species richness: S) varied from two to 64 taxa per grab (average = 17), and species diversity ( $H'$ ) varied from 0.40 to 4.49 (average = 2.62). The mean number of species

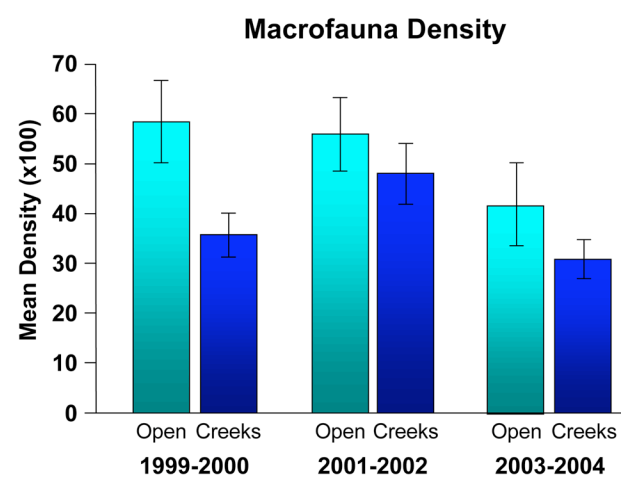


Figure 3.4.4. Mean density (number per m<sup>2</sup>) of benthic fauna collected in open water and tidal creek habitats during the three study periods.

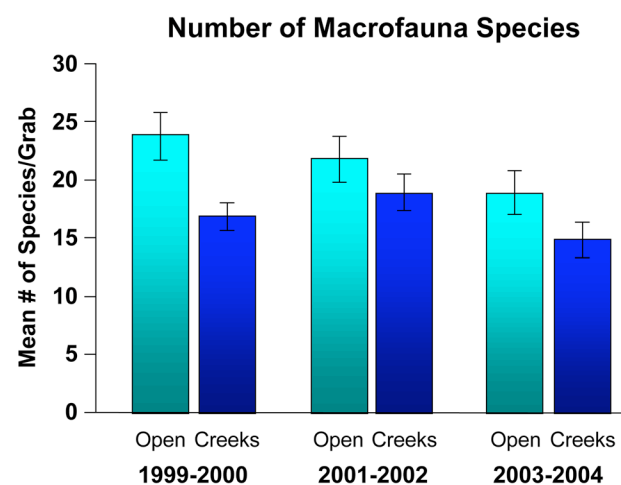


Figure 3.4.5. Mean number of species of benthic fauna collected in open water and tidal creek habitats during the three study periods.